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EVALUATION OF THE COMPOSITION AND ORGANOLEPTIC PROPERTIES OF PROCESSED SESAME (*Sesamum indicum*), “ACHA” (*Digitaria exilis*) And Seedless Breadfruit (*Artocarpus altilis*).

FLOURS AND THEIR PRODUCTS

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This work is dedicated to my brother,
Rev. Father Mike Uzochukwu Nwokocha,
for his unrelenting moral support.
ACKNOWLEDGEMENT

My sincere and unquelled thanks are given to Almighty Father for his grace and direction that enabled me complete this work.

I am especially indebted to my supervisor, Dr. (Mrs) N.M. Nnam, whose dedicated attention, patience and motherly advice in the preparation and compilation of this research work will ever be cherished. I am also indebted to Professor I.C. Obiobua who was always ready and willing with his fatherly advice and constructive criticisms.

I am grateful to Professor D.O. Nnanyeugo, Professor I.U. Obi, Dr. (Mrs) E.C. Okeke, and Dr. (Mrs) H.N. Ene-O tongue for their encouragement and useful suggestions during the study. I thank Mr. E.C.N. Omechukwu and Mr. S.I. Umeh for their assistance during the laboratory analysis and also Dr. L.R. Nwakalor for his much valued guidance in statistical analysis.

My most special thanks goes to Rev. Mother Ifechukwu Udogah, my mother General and to all the Rev. Sisters in the Daughters of Divine Love Congregation, my religious family for their care, support and sacrifices, both morally and financially.

I can never thank my parents Sir and Lady M.A. Nwokocha (KSM), brothers and sisters enough, for the understanding, prayer and love showered on me throughout the hectic period. I thank my brother Rev. Father Mike U. Nwokocha in a special way for his dedicated prayers and encouragement. I am equally grateful to Rev. Father (Dr) R.C. Amaatu C.S. Sp. for everything.
I thank Ms. E.A. Udenta for her ever ready assistance. Finally to all my friends, departmental staff and colleagues who in one way or the other helped to make this work a reality, I say a big thank you.

Okwuchi Maria Nwokocho
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ABSTRACT

The study was designed to determine the nutritive value of processed (dehulled, sprouted and boiled) sesame (*Sesamum indicum*), “Acha” (*Digitaria exilis*) and seedless breadfruit (*Artocarpus altilis*) flours and the organoleptic properties of the products and their flour blends. Sesame was dehulled manually, “acha” was sprouted for 48h, and breadfruit was boiled for 10min. The samples were milled into fine flours and combined in ratios of 70:15:15, 60:25:15, 60:15:25:15, 60:25:15 (protein basis) of sesame, “acha” and seedless breadfruit to produce the blends. Biscuits and gruels were developed from the composite flours. The flours, flour blends and their products were chemically evaluated using standard methods while the products from the flour blends were organoleptically tested for acceptability. Dehulled sesame contained higher (p<0.05) protein, carbohydrate, iron, phosphorus, zinc and ascorbate than the undeheulled sample. Sprouting increased carbohydrate, fibre, fat, zinc and ascorbate levels of “acha” while protein, ash and phosphorus were decreased. Boiling improved protein, calcium and phosphorus levels of breadfruit. Processing of sesame, “acha” and seedless breadfruit to flour resulted in a decrease in cyanide, tannin and phytate levels of the flours.
The biscuits from the flour blends contained appreciable quantities of phosphorus, calcium and ascorbate and fair levels of protein (9.02 - 14 - 30%). The gruels also contained appreciable quantities of calcium, magnesium and ascorbate and fair levels of protein (10.93 - 18.87%). The biscuit from the processed 70:15:15 mixture had the highest protein level (14.30%) however, the value was comparable with others (p<0.05). The biscuit samples that had the highest nutrient levels were those from the processed 70:15:15 and 15:60:25 composite flours, respectively. The methods applied to produce the flour improved flavour and general acceptability of the products. The biscuits from the 60:25:15 and 60:15:25 mixtures were preferred to others, while the gruel from 60:25:15 was preferred. The processed foods had nutritional advantages over the unprocessed in most of the parameters tested.
CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND STATEMENT

There is high rate of protein - energy - malnutrition (PEM) in the developing countries (Latham, 1997). In Nigeria, it is prevalent among the low income families. This is partly because high protein foods like meat, milk, fish, egg, poultry and other animal foods are most often not included in the diet because of their high cost. The use of cheap nutritious mixed diets, based on locally available and acceptable plant foods in Nigeria, could provide an alternative to the expensive animal foods. Ignorance of the possible combinations of the available plant foods in the diet also contributes to PEM. Nestlé (1978) suggested that the production of high quality varieties of plant foods as well as adequate complementation and supplementation will offer the most and least expensive immediate practical means of reducing PEM in the developing nations.

Global nutrition surveys revealed that the protein value of a food is related to the provisional pattern of essential amino acid (EAA). This is dependent on the amino acid balance of the protein in food eaten together. Cereal foods are high in sulphur containing amino acids (cystine and methionine) but deficit in lysine. Legumes contain high levels of lysine. They are good sources of B-complex vitamins but poor in sulphur containing amino acids. The exceptionally high
methionine and cystine contents of the cereal "acha" hungry rice make it an excellent complement to legumes (Benito et al., 1988). Fruits are good sources of vitamins and minerals. Breadfruits (Artocarpus altilis) - the seedless variety is relatively high in calcium (Ca), ascorbic acid, phosphorus (P), vitamin A, iron (Fe) (Macrae et al., 1993). Thus, the mutual supplementation of breadfruit to "acha" and sesame would highly improve their nutritional quality.

Of concern however, is the presence of antinutritional and anti physiological factors present in plant foods. They limit their food value (Osho, 1989; Okaka et al., 1992). In addition, dietary bulk in plant foods is not advantageous in the feeding of young children (King and Burgess, 1993). Studies have shown that processing of foods decreases levels of antinutrients and toxins. There is improvement in flavour, texture, colour, nutrient density and availability (Nout, 1993; FAO, 1997; Enwere, 1998). The practice of sprouting legumes before consumption increases the level of water soluble vitamins including ascorbic acid which is virtually absent in dry seeds. Sprouted cereals in the form of the malt are also good sources of B-complex vitamins. Sprouts are known to decrease bulk and increase nutrient density (Latham, 1997). Soaking removes some of the toxic substances naturally present in plant foods. Boiling improves the nutritive value of some foods as well as texture and palatability (Enwere, 1998). Dehulling reduces levels of antinutrient, particularly those found on the hulls (Enwere, 1998).
Sesame and "acha" are widely grown in northern Nigeria, while breadfruit is grown in the southern part of Nigeria. The nutritive value of processed blends of these food crops are not well known. This is an obvious setback in the proper and extensive utilization of the foods for improved nutrition. Processing could improve the food value of these indigenous crops and extend their food uses. This could help reduce the rate of PEM in the country. The main thrust of this work was to formulate composite flours and develop products from unprocessed and processed "acha," sesame and breadfruit and assess the potential nutritional quality and acceptability of the products.

1.2 STATEMENT OF PROBLEM

There is high incidence of PEM in Nigeria, particularly amongst the poor segments of the society. This is because of high reliance on plant foods which are not nutritionally balanced when taken singly without adequate processing. “Acha” sesame and breadfruit are mainly consumed unsupplemented without adequate processing. This affects amino acid and other nutrient balance. The problem of this research was to explore the use of conventionally processed sesame, “acha” and breadfruit flours as blends to develop products that hopefully will improve the general nutritional status of the Nigeria populace.
1.3 SIGNIFICANCE OF THE STUDY

1. The result of the study will provide more information on the nutrient composition of these local foods. The information obtained in the study could be valuable in the proposed food composition table for Nigeria.

2. Nutritionists and extension workers will use the findings of this study to train mothers on how to formulate balanced diet from sesame, "acha" and breadfruit.

3. The study will help both the government food policy makers and the food industries to produce more nutritious and cheap foods from sesame, "acha" and breadfruit.

4. The results of the study will open up other food uses of the food crops and provide avenue for vegetarians to have more opportunity to select and consume balanced diets.

1.4 OBJECTIVE OF THE STUDY

The objectives of the study were:

1. To determine the nutrient and anti-nutrient composition of unprocessed and processed sesame, "acha" and breadfruit flours.

2. To develop products (biscuits and gruels) from sesame, "acha" and breadfruit composite flour blends.

3. To determine nutrient composition and organoleptic attributes and acceptability of the products.
CHAPTER TWO
LITERATURE REVIEW

The high rate of protein-energy malnutrition (PEM) in most developing countries is due to consumption of foods low in energy and protein. Foods of animal origin are rarely eaten because of their high cost (Enwere, 1998). The use of nutritious mixed protein diets based on locally available and acceptable legumes, cereals and fruits could provide an alternative to the expensive animal foods.

Sesame (legume) “acha” (cereal) and breadfruit are some under exploited food crops whose blends could be used to alleviate the nutrient gap experienced by many people in different parts of the country.

2.1 LEGUMES

Legumes are food plants which have pods that open along two seams when the seeds are ripe (Tver and Russell, 1989). Beans, peas, lentils, groundnuts and their like belong to the botanical family of leguminosae. Their edible seeds are called legumes or pulsea (Latham, 1997). The legume family, Leguminosae, is an extremely large and cosmopolitan one and all the major continents have provided members of this family that have become food for man (Enwere, 1998).

Some of the legumes used as food for humans include: chick pea (Cicer arietinum); pigeon pea or Red gram (Cajanus cajan); soybean (Glycine max); lentils (Lens esculenta); peas (Pisum sativum); broad beans or faba beans (Vicia
faba); bambara groundnut (*Vigna subterranea*); sesame or benniseed (*Sesamum indicum*); african yam bean (*Sphenostylis stenocarpa*); cowpea (*Vigna unguiculata*); lima bean (*Phaseolus lunatus*); pea nut (*Arachis hypogaea*); kidney bean (*Phaseolus vulgaris*); horse gram (*Dolichos heglorus*); and locust bean (*Parkia biglobosa*). In Nigeria cowpea is widely consumed (Nnam, 1994; Latham, 1997; Enwere, 1998).

Legume seeds are divided into two types - pulses and oil seeds. Pulses store their food energy as starch e.g pea, beans and lentils while the oil seeds store food energy as lipid material e.g. soybean, sesame and groundnuts (Nnam, 1994). There are more than 11,000 species of legumes (Tver and Russell, 1989).

Legumes were among the earliest food crops to be cultivated by man. Their history as cultivated crops goes back to neolithic times when man was passing from hunting and food gathering into the food producing stages (Aykroyd and Joyce, 1981). The roots of many species of legumes contain nodules which are the habitat of bacteria with the power of fixing atmospheric nitrogen. The nitrogen is liberated when the roots decay, so that the leguminosae enrich poor soil and are of great values to crop rotation (Latham, 1997).

2.1.1 IMPORTANCE OF LEGUMES AS FOOD FOR MAN

Legumes rank second to the grasses as food for man but perhaps serve in a greater variety of ways than the grasses. Legumes were at one time regarded as the poor man's meat or meat substitute in different parts of the world (Tver and
Russell, 1989; Latham, 1997). This was because the poorer class in society who could not afford to buy meat, fish, and egg as protein source could afford to buy beans to satisfy their protein needs.

LaBell (1989) reported that beans are the vegetable most Americans eat as a side dish or in an occasional bowl of chili. It is emerging as a major nutritional ingredient. Bean enthusiasts recommend them as a low fat source of proteins, carbohydrates, fibre and other nutrients. The fibre in beans is recognised as helping to prevent some types of cancer, aids the metabolism of diabetics. It helps dieters satisfy their appetites without overloading on calories. Some recent studies have shown that the fibre in beans fights cholesterol as fiercely as the American oat bean diet (LaBell, 1989).

Legumes are usually consumed in combination with cereals such as rice, maize, millet and sorghum. They are some times combined with roots and tubers such as yam, cassava, potato, and cocoyam or eaten with plantain and banana. Studies have shown that legumes proteins complement cereal proteins to provide an ideal source of dietary protein of vegetable origin for humans (Benitu et al., 1986). Latham (1997), observed that most legumes contain more protein than meat, however, the protein is of slightly lower quality because it has less methionine. When pulses and cereals are eaten together at one meal they supply a protein mixture that contains desirable pattern of all the amino acids, which improves the protein value of the diet.
Legume seeds can be converted into flour or paste and used for the preparation of akara (fried paste) and moi moi (steamed paste). Legume flour has been processed and used in many other food preparations such as baby foods and baked products (McWatters and Cherry 1982; Mostafa et al., 1986; Uwaechuta, and Nnanyelugo 1987). In general, vegetable proteins have recently received increased attention as low cost replacement for animal protein, both as meat substitutes and as milk substitutes in infant formulas and supplementary feeding mixtures (Fatima et al. 1991). Much research has been done during recent years on the value of plant protein in preventing and curing protein malnutrition. In India, children with kwashiorkor were given chick pea in the form of flour made from 48h germinated grains. The flour was mixed with banana, unrefined sugar and water and autoclaved, giving a product resembling a steamed cake. Taken in amount of 60g of protein daily, this preparation produced a good clinical response, comparable to that seen in similar children receiving skim milk powders. Edema disappeared and weight gains were satisfactory. It was reported that the chick pea supplement controlled diarrhea more rapidly than the skim milk supplement. On the other hand, the level of serum albumin, an important criterion of protein utilization, rose more slowly in the children given the chick pea mixture than in those receiving skim milk protein. In Indian trials, a 1:1 mixture of chick pea and green gram (Phaseolus aureus) was less effective than chick pea alone (Kordulas, 1990; Okaka, 1997).
2.1.2 NUTRITIVE VALUE OF LEGUMES

Legumes are very important from a nutritional point of view. This is because they are widely available vegetable food containing good quantities of protein and B-complex vitamins in addition to carbohydrate (CHO). Among vegetable crops, legume grains contain the highest amount of protein which is above twice the level found in cereal grains and significantly more than the level in roots and tubers (Latham, 1997). The protein content ranges generally from 20-40% for most legumes (Ene-Obong and Carnovale, 1992; Apata and Ologhobo, 1994). Elegbode (1998) observed that the protein content of legume ranges from 20-25%, the variability within species and between location may be as high as 10%. He maintained that despite these differences, legume protein is still considered of good quality though deficient in some amino acids cystine and methionine. The CHO content ranges from 23% in groundnut to 66% in bambara groundnut; pigeon pea and lima bean and other seed grains (Jayas and Venkataraman, 1980; FAO, 1982; Ene-Obong and Carnovale, 1992; Apata and Ologhobo, 1994).

Legumes are generally low in fat. The value ranges from 1 to 5%. The oil-seeds have a range of lipid content from about 18% in soybean to as high as 43% in groundnut and 50 to 57% in sesame (Irvine, 1979; Ene-Obong and Carnovale, 1992; Apata and Ologhobo, 1994). Some legumes, like groundnut, soybean and
sesame are rich in oil (Latham, 1997). They supplement very well the predominantly CHO diet based on cereals.

Latham (1997) further explained that most legumes usually contain good quantities of thiamin, riboflavin and niacin. They are also richer in iron (Fe) and calcium (Ca) than most of the cereals. Okaka et al. (1992) observed that the practice of sprouting legumes before consumption increases their water soluble vitamin content, including ascorbic acid which is virtually absent in dry seed.

2.1.3 SESAME - BENNESEED (Sesamum indicum),

Benniseed is also known as sesame Sim-sim or gingelly (Irvine, 1979). It is an important crop in Nigeria. In some areas it is grown almost entirely for export because of its seeds that yield valuable oil. Sesame is grown mainly in northern regions of Nigeria (Irvine, 1979).

Irvine (1979) reported that there are two species of sesame that are sometimes hard to distinguish.

1. *Sesamum indicum*, often called 'Gingelly'. This is believed to have originated in tropical Africa, although it is widely grown in India. It is an erect, simple or branched herb growing up to 6 ft tall with grooved stems. The fruits are 1 to 1½ inches long and have conspicuous beaks. The seeds are almost smooth.

2. *Sesamum radiatum*: This is found throughout the tropics and is also of African origin. It is a herb about 4 ft tall, with a strong scent. The leaves
are always simple, the upper leaves narrow and oblong, the 1½ inches below are reddish-purple with a broad yellow streak in the tube. The fruits are 1" x ½". The seeds are brownish-yellow or purple-black spotted. The herb occurs wild, but is some times cultivated. It may cross with Sesamum indicum. The seeds vary in colour from white, pink, brown and orange to red and black. The white-pink, or red-seeded form are said to be better for use as human food than the black-seeded kind which are used commercially. The white seeded forms are probably from Sesamum indicum, the black seeded are used as an adulterant and have a lower oil content. These are called 'black benuncios; and are mostly from Sesamum radiatum. Sesamum siamense is another species, commonly grown in parts of Ivory coast (Irvine, 1979).

2.1.4 PRODUCTION

Sesamum thrives in the drier parts away from the closed forest (Irvine, 1979). It needs good rain at sowing and during the first two months of growth. The crop can grow in lower rainfall regions, provided that it is on rich soil and is not waterlogged and on sandy loams and loam soil. As it can produce a crop on quite light or poor soil, it tends to be given little care.

Irvine (1979) noted that in northern Ghana, sesame is sown in July and harvested from December to February. In Sierra Leone, it is sown in May and harvest in November, in Nigeria, it is sown in April and harvested from July to
August. It is usually a sole crop in Nigeria but with irrigation it might be possible to grow two crops a year. The Tiv in Nigeria manure it with ashes from sorghum. It is often grown as the last crop in a rotation and may then yield more oil. The crop grows quickly and matures after two to three months. It needs dry weather at sowing and harvesting (Irvine, 1979).

2.1.5 UTILIZATION

According to Irvine (1979), West African sesame contains 50 to 57% oil. This is an important edible oil used in the developed countries for margarine and fine grade machine oil. In Africa it is used for cooking, while inferior grades are used for soap, lighting or fuel. It yields by expression 42 to 48 percent of oil which is of good quality, semi drying, and clear. It keeps well and have no smell, can be used as an olive oil substitute.

Oil can be extracted by power press, but the usual African method is to crush and boil the seed, and skin off the oil. When a power press is to be used, the seeds are ground, heated and put into sacks, which are put into the press while hot. The oil produced is clear and ready to be used or tinned. Too much pressing give more oil, but it is less clear and darken in colour, with a stronger taste. The meal left over is made into cake for cattle or pigs. It is also used as a fertilizer (Irvine, 1979). Seed cake which remains after oil extraction is rich in protein, and is made into hot curries in India (FAO, 1988).
Other uses:

According to (FAO, 1988) the seeds are eaten in soups, fried or boiled with maize in southern Africa. The seed coat is usually removed. When roasted, they are eaten as a relish with other foods. In Zimbabwe, they are cooked with leaves of pumpkin; mixed with porridge or with caramelized sugar to make delicious seed cakes, popular throughout Africa and Asia. The seeds may be sprinkled on top of breads and pastry. They are used in the manufacture of the traditional Mediterranean sweet meat ‘halva’. Throughout India sesame seeds are an important ingredient of many sweetmeats. In Venezuela a drink is prepared from toasted, crushed seeds, to which milk and sugar are added. The pounded seeds are used as an alternative to groundnuts (FAO, 1988).

Sesame oil is used in the manufacture of soaps, paints, lubricants, carrier for medicinal drugs, in perfumes, cosmetics and as an illuminant. The seeds are used to stimulate lactation and menstrual flow; treatment of piles, coughs as an aphrodisiac, and as soothing dressing for burns. The leaves are used to treat kidney and bladder infections and to promote hair growth. The young shoots and leaves are used as a soup vegetable in western Africa. The juice is used to destroy hair lice (FAO, 1988).
2.1.6 CHEMICAL COMPOSITION AND NUTRITIVE VALUE OF SESAME

FAO (1988) observed that the seeds are rich in protein, fat, calcium (Ca) and phosphorus (P) and a fair source of vitamin B1, with small amounts of trace elements- zinc (Zn), iodine (I), cobalt (Co) and molybdenum (Mo). Most of the Ca is present as oxalate in the seed coat, which is removed on preparation. The protein is rich in tryptophan and sulphur containing amino acids, (SAA) particularly methionine. Sesame seeds eaten with cereals which are high in lysine, make a balance mix and their fat content also make them a valuable supplement to cereals.

Latham (1997) noted that the seeds contain about 50 percent fat and 20 percent protein. They are also rich in Ca and contain useful quantities of carotene, iron (Fe) and B-complex vitamins. Sesame can form a nutritious addition to the diet. Panty and Arnold (1971) observed that sesame is one of the several seeds which are produced mainly for their oil content. After removal of the oil, the seed cake, contains about 40 to 50 percent protein of moderate to good biological value (BV).

2.1.7 DELETERIOUS CONSTITUENTS PRESENT IN SESAME SEED

Selenium has been found to occur in sesame seeds grown on seleniferous soils of some countries. If selenium is present at a level higher than 300ppb, it is toxic. Oxalate acid is present in the form of calcium oxalate in the husk of sesame
seeds. This can be eliminated by dehusking and the dehusked sesame seed is almost free of oxalic acid. The hull, which forms about 12% of the seed is rich in fibre and oxalates and contain bitter principles as such it must be removed for preparing edible meal (FAO, 1988).

2.2 CEREALS

Cereals are edible seeds of the grass family, which serve as industrial raw materials and staple foods the world over (Tver and Russell, 1989). World cultivated cereals include rice, maize, wheat, "ncha" (hungry rice), barley, oats, sorghum, rye and maize. A new cereal of considerable interest is triticale, a cross between wheat and rye (Latham, 1997). The common grains have a roughly similar composition.

2.2.1 CHEMICAL COMPOSITION AND NUTRITIVE VALUE OF CEREALS

Although the shape and size of the seed may be different, all cereal grains have a fairly similar structure and nutritive value. 100 g of whole grain provide about 350 kcal, 8 to 12 g of protein and useful amounts of Ca, Fe, and the B-complex vitamins. In their dry state cereal grains are completely lacking in vitamin C, except for yellow maize, contain no carotene (provitamin A). For a balanced diet, cereals should be supplemented with foods rich in protein, minerals and vitamins A and C (Latham, 1997).

Cereal structure consists of:
- the husk of cellulose, which has no nutritive value for humans;
- the pericarp and testa, two rather fibrous layers containing few nutrients;
- the aleurone layer, is rich in protein, vitamins and minerals;
- the nutrient-rich embryo or germ;
- the endosperm, comprising more than half of the grain and consisting mainly of starch. The embryo is the part of the grain that sprouts. It is very rich in nutrients. The embryo often contains 50 percent of thiamin, 30 percent of the riboflavin and 30 percent of the niacin of the whole grain (Latham, 1997).

P is the major mineral contribution of most grains (Tyer and Russell, 1989). When cereal grains are consumed in their entirety an adequate supply of the B-complex vitamin is ensured. Maize is an exception because the nicotinic acid is biologically unavailable (Nnam, 1994).

2.2.2 "ACHA" - HUNGRY RICE (Digitaria exilis)

"Acha" (Digitaria exilis) also known as hungry rice is indigenous to West Africa where it is grown for its edible grains or its straw (Okoh, 1998). "Acha" grain has been found to be the smallest cultivated cereal grain. It is 0.023 mm in width and 1.0 - 1.1 mm in length. It has an average grain weight of 0.46 g/1000 kernels (UNECA, 1985). In Nigeria, "acha" grains form the stable cereal of the hill tribes of Jos and Bauchi, where the poor sandy soil will not support the growth of some more popular cereals (Okoh, 1998). It is grown in various parts of Sierra Leone, Guinea, Conakry, Guinea Bissau, and Benin Republic. "Acha" is
considered the oldest indigenous cereal in West Africa. It has been cultivated since 5,000 B.C.

**Agronomy**

There is very little information in the literature on "acha" because it is one of the lesser known cereals. According to Irvine (1979), the planting season of "acha" is normally between June and July. The crop takes about three months to mature and produce seed. It is harvested between November and December.

"Acha" is the world fastest maturing grain (Irvine, 1979). Certain varieties mature 6-8 weeks after planting. It grows in areas with 40-50 inch of rain on poor, sandy, or ironstone soil. It gives a reasonable yield on shallow, infertile soils where other crops fail or survive only with difficulty, and on rocky places such as the Bauchi Plateau. After harvest it is left on the stock to dry. The grain is threshed out and milled to obtain the kernel. The "acha" kernel is the edible portion of the grain.

During storage, weevils attack the grain. The webs they produce may cause the grain to stick together and form tiny nodules causing off flavour and odours. This effect can be controlled by thoroughly washing the grain, drying it and keeping in air tight containers such as plastic containers or tin cans with tight covers.

2.2.3. **Food Uses**

The grain is used in the preparation of porridge and other dishes in Nigeria. Local population of Plateau State and its diaspora prepare a popular porridge called 'gwote' with the grain. Both the grain and the straw are suitable for feeding
ruminants. The grains are used for feeding pigs and poultry (Enwere, 1998). 'Acha' is also used to make 'twao', 'burabisko', pap, or may be ground and mixed with other cereals and used for the same purposes. It is also used for beer brewing. 'Acha' grass is burnt to ashes to produce "toka" a kind of local potash (Irvine, 1979). The small grain with an attractive flavour is used to ground into flour and mix with the meal of other cereals for baking (Parseglove, 1978). Temple and Bassa (1991) reported its uses for cooking in various forms with meat, fish, legumes and vegetables. It's flavour is used for local beverages. It is used in combination with other cereals as meals (Spore, 1995). Nzeribe and Nwasike (1995) reported that when mixed with sorghum or pearl millet seeds, it could produce beer worth similar or even better than barley. Most valuable of all, 'acha' has the potential for reducing human misery during "hungry times" (NAS, 1996).

2.2.4 CHEMICAL COMPOSITION AND NUTRITIVE VALUE OF "ACHA"

NAS (1996) described "acha" as one of the most nutritious of all cereal grains. Its seed is rich in methionine and cystine and this makes it an excellent complement to legumes (Benito et al., 1986). The crude fat content (2-10%) of "acha" is similar to those of sorghum, millet and wheat but lower than the values for maize and millet (Nwasike et al., 1987; Temple and Bassa, 1991). "Acha" has a proximate composition of: protein 9.0%, CHO 75.0% (NAS, 1996); fat 2.10%.
crude fibre 3.3%, mineral salts 2.44% (Nwashe et al., 1987; Temple and Bassa, 1991; NAS, 1996).

"Acha" has high mineral content of calcium (Ca) 7.56 mg, zinc (Zn) 4.23 mg, magnesium (Mg) 84.90 mg, potassium 1090 mg, iron 13.36 mg, sodium 85 mg, phosphorus 0.177 mg (Adeyeye and Ajewole, 1992; NAS, 1992).

The lysine content (3.1%) of "acha" is expectedly lower than that of the FAO reference protein. It is similar to wheat, lower than rice, barley, oats and higher than maize and sorghum (Doll, 1984). Values of other amino acids are as follows: phenylalanine 5.7%, valine 5.5%, leucine 10.5%, isoleucine 4.0%, cystine 3.06%, glutamic acid 6.93% (NAS, 1996; Temple and Bassa, 1991).

"Acha" is slightly inferior in protein to other cereals such as millet, rice and maize. The grain should be balanced with high quality protein. It has been recognized as the most economic source of carbohydrate food for man in the areas with poor soil where they are more economically produced than other cereal. The seed grain is often recommended for diabetic patients because of its high digestible total nutrient (NAS, 1996).

2.3 FRUITS

Fruits are the edible portion of the reproductive body of the seed of a plant. which usually involve the pulp associated with the seed (Tver and Russell, 1989). They are plant parts which have succulent aromatic, and fragrant characteristics. They are usually sweet or are sweetened before eating. Fruits are usually eaten
raw or as desserts or appetizers (Enwere 1998). Fruits form about 4% of the world’s food supply (Kilgours, 1987). It is known that fruits and nuts form an integral part of the African diet and are consumed as relishes and snacks. The varieties of fruits available at any one time in a given area depend on the climate, the local taste for fruits, the species cultivated and the season (Achinewhu, 1983; Ogbonna, 1991; Latham, 1997). Fruits are rich in vitamins, minerals, fats and sugar (Achinewhu, 1983; Ogbonna, 1991). Despite this, fruits have not been given a pride of place in the diets of the Nigerians. The main reason for the neglect is ignorance of the nutritive values of most of the fruits which abound in our environment. Other reasons include the rising cost of fruits, problems of storage of this gaseous commodity and that of distribution (Tindall and Florence, 1983).

Some food crops used as fruits include: Apples (Pyrus malus), apricots (Prunus armeniaca), straw berries (Fragaria virgiana), grapes (Vitis vinifera), pears (Pyrus communis), plums (Prunus domestica) figs (Ficus carica), seedless breadfruit (Artocarpus altilis), soursop (Annona muricata), banana (Musa spp), jackfruit (Artocarpus integrifolia), and mangoes (Mangifera indica) avocado pear (Persea americana), pawpaw or papaya (Carica papaya), tomatoes (Lycopersicon Lycopersum), cashew fruit (Anacardium occidentale). (Purseglove, 1991; Enwere, 1998; Umoh, 1998).
Fruits can be processed into other food products or used as ingredients in different foods. These products include: fruit salad, juices, wines, canned fruits, pecans, jellies, marmalades, jams pastes, purées, and others (Enwere, 1998). Flour and baby foods are prepared from plantains and bananas when mixed with other ingredients (Ogazi, 1989). Plantain flour is mixed with wheat or with other flours like soyabens, groundnut, cowpeas, and used in making bread, cake and pancakes (Enwere, 1998).

2.3.1 CHEMICAL COMPOSITION OF FRUITS.

Fruits when consumed in good quantities could supply about 9% the calories in the diet, provide about 92% of ascorbic acid, 49% of vitamin A and 30% of B-complex vitamins (Annette and Jo-Ann, 1985). According to Latham (1997) the main nutritive value of fruits is their content of ascorbic acid, which is often high. Some fruits also contain useful quantities of carotene. Fruits (except the avacado and a few others) contain very little fat or protein and usually no starch. Th CHO is present in the form of various sugars. Most fruits are poor to fair in their content of the B-complex vitamins. Dried fruits are good sources of energy and Fe but are poor in their content of ascorbic acid (Okaka et al., 1992).

2.3.2 SEEDLESS BREADFRUIT (Artocarpus Altilis)

According to Ragone (1988), the breadfruit is a widely grown and various tree fruit which is used as a vegetable crop. Breadfruit is a member of the genus Artocarpus (Family Moraceae) which contains about 50 species of trees
that grow in the hot, moist regions of the south east Asian tropics and in the
Pacific Islands. There are two species of breadfruit in the Pacific Islands:
Artocarpus altius (A. altius) (Synonym Artocarpus communis) and Artocarpus
mARIANNensis (A. mariannensis).

There are both seeded and seedless form of A. altius. The seeded forms
are most common in the Western South Pacific and appear to be indigenous in
New Guinea, where they grow wild in the lowland forests. The seedless form of
A. altius are widely distributed and the greatest diversity of seedless cultivars
occur in eastern Polynesia and parts of the Caroline Islands. European voyagers
introduced seedless breadfruit from Polynesia throughout the tropical world in the
late 17th and 18th centuries. A spiny-seeded breadfruit similar to A. altius is
found in New Guinea, Island Southeast Asia, and the Philippines. It is recognised
as a separate species.

2.3.3 FRUIT MORPHOLOGY

Ragone (1988) described the fruit of the breadfruit as a highly specialized
structure, a syncarp, composed of 1500 to 2000 flowers attached to the fruit axis
or core. The core contains numerous latex tubes and large vascular bundles which
discolour rapidly upon cutting. As the fruit develops, it grows vigorously and
becomes fleshy at maturity, forming the edible portion of the fruit.

The fruits of A. altius are oblong, ranging from 10 to 20cm in diameter.
The yellowish green rind is marked with conical processes, up to 3mm long. The
creamy white or pale yellow flesh is soft and pulpy when mature, surrounding a spongy core. Numerous, tiny aborted seeds normally surround the core (Ragone, 1988).

2.3.4 TRADITIONAL AND COMMERCIAL IMPORTANCE OF BREADFRUIT

According to Wooton and Tumaalii (1984), breadfruit is more important as a subsistence crop than as a commercial crop in most areas of the world, especially in the Pacific Islands, where it is an important staple crop. It is a major source of food throughout Micronesia, especially on the atolls, where the breadfruit is the main subsistence crop along with cyrtosperma pandanus and coconut. In the South Pacific, breadfruit is of prime importance in the eastern Solomon Islands. In the Pacific Islands, the fruits are typically roasted or boiled, and occasionally fried as chips. Breadfruit chips are commercially made and marketed for local consumption on a small scale in Western Samoa, Saipan, and Hawaii. It is locally consumed in the Caribbean Islands, especially in Jamaica, where it is typically boiled or roasted. Fresh fruits are occasionally exported to the USA and commercial production of breadfruit flour has been attempted. Sliced, boiled breadfruit canned in brine is also produced on a small scale for local consumption and export. Breadfruit chips are produced and marketed on several Caribbean Islands (Wooton and Tumaalii, 1984).
2.3.5 CHEMICAL COMPOSITION

Breadfruit is an important source of energy, high in CHO, but low in fats and protein. It contains about 71 kcal of energy, 79.5 g moisture, 1.5 g protein, 0.2 g fat, CHO 15.8 g, Vitamin A 30 IU, Vitamin B1 0.04 mg, ascorbic acid 21 mg, Ca 40 mg, phosphorus 30 mg, Fe 0.5 mg (Gopalan et al., 1985).

2.3.6 PRESERVATION OF THE BREADFRUIT

According to Parker (1967) the keeping quality of breadfruit is limited by a high post-harvest rate of respiration. Fruits soften within 1-3 days. Cooked breadfruit can be frozen, and this storage method deserves greater attention.

Parker (1967) noted that the breadfruit can be prepared, fermented and stored in the pit. The pit storage is a semi-aerobic fermentation process involving intense acidification which reduces fruit to a sour paste. Mature and ripe fruit are peeled, halved and allowed to soften. This is achieved in the atolls by soaking in a lagoon for 1-2 days. The softened fruits are placed in a leaf-lined pit and covered with leaves, a layer of soil, and then rocks. After 2-3 weeks the fermented breadfruit pulp is ready for use. It is always washed and cooked before being eaten. Fermented breadfruit can be stored for 1-2 years in the pit, and the leaves are replaced as needed during the storage period. A cleaner, more uniform product can be prepared by placing the softened fruits in air tight plastic containers.
Drying is another common method. Ripe fruits are boiled until soft, then sliced into pieces which are dried in the sun for 3-4 days. After the fruits are peeled and cut into bite-sized pieces, the pieces are dried on racks for 8-24 h over a fire. Breadfruit dried in this manner can be stored for up to a year in leaf-lined baskets and indefinitely in airtight plastic or glass containers. Dried breadfruit is usually eaten without additional preparation but it may be ground into flour and mixed with water or coconut milk to make a porridge.

While numerous traditional methods have been developed to process and store breadfruit, this easy-to-grow nutritious CHO fruit will never become more than a locally important crop unless economical, reliable methods of both extending its shelf life and commercially processing it are developed (Parker, 1967).

This vegetable tree fruit, the seedless breadfruit can be found in both the Western and Eastern parts of Nigeria. There is little or no information about this nutritious CHO fruit in Nigeria. Research attention is needed on the fruit to popularize its uses.

2.4 THE ANTINUTRIENTS

Compounds, which act to reduce nutrient utilization on food intake, are often referred to as antinutritional factors (ANF) (Osagie, 1998). Legume seeds, cereal grains and fruits are known to contain the antinutritional factors (tannins, phytates, cyanides, flatulence and protease). These militate against the nutritional
potential of the seeds for both humans and animals. Although toxic compounds are widely distributed in the plant kingdom, it is generally considered that tropical legumes contain a more complex array of these substances than any other crop species. The toxic factor may occur in all parts of the plant, but the seed is normally the most concentrated source (Osagie, 1998).

2.4.1 FLATULENCE FACTORS

Flatulence is a problem associated with the consumption of food legumes. Okaka et al. (1992) reported the primary cause of flatulence to be the production of abdominal gas when food items such as melon seed and cowpeas are consumed in appreciable quantities.

Flatulence factors are eliminated by proper heat treatment and dehulling (Okaka, et al., 1992; Enwere, 1998). It is known that oligosaccharides are concentrated in the bean hull or testa and are at a low level in the cotyledons. Enwere (1998) made it known that the removal of hull or testa during dehulling, significantly reduces the level of oligosaccharides in the beans and their products.

2.4.2 TANNINS

Any plant polyphenolic substance with a molecular weight greater than about 500 can be considered to be a tannin. The two distinctive groups were the hydrolyzable tannins, because they may be readily hydrolysed into a mixture of CHO and phenols and condensed tannins which are complex flavonoid polymers (Osagie, 1998). FAO (1995) referred to tannins as polymers resulting from
condensation of flavour -3-ols. Gupta and Haslam (1980) referred to sorghum tannins as procyanidins because they thought that cyanidin was usually the sole anthocyanidin involved.

Tannins may decrease protein quality by decreasing digestibility, and palatability. The other nutritional effects which have been attributed to tannins include damage to the intestinal tract, toxicity of tannin absorbed from the gut, interference with the absorption of Fe, and a possible carcinogenic effect (Radhakrishna and Sivaprasisal, 1980; Grifths, 1985; Asquith and Butler, 1986).

Growth retardation was observed in chicks fed high-tannin sorghum. Tannins in grains impart an astringent taste which affects palatability, reducing food intake and consequently body growth (Butler et al., 1984). It has been suggested that tannins play a major role in the plant's defence against fungi and insects. Dreyer et al., (1981) observed that polyphenols protect seedlings from insect attack. It has known that tannins are the most abundant phenolic compound in brown bird resistant sorghum. Tannins, while conferring the agronomic advantage of bird resistance, adversely affect the grain's nutritional quality (Salunkhe et al., 1982; Butler et al., 1984; 1986; Salunkhe et al., 1990).

Some processing methods could be used to eliminate tannins from grains or seeds. They include: Germination (Udayasekhara Rao and Deosthale, 1988; Osuntogun et al., 1989), cooking (Price et al., 1980; Bressani and Elias, 1980); soaking which reduced the presence of polyphenols due to leaching in the
soakwater (Deshpande et al., 1982; Butter, 1988), dehulling which eliminates tannin in legume seeds (Walker and Kochhar, 1982).

2.4.3 PHYTATE

Phytate is a storage form of phosphorus which is found in plant seeds and in many roots and tubers (Dipak and Mukherjee, 1986). Phytic acid has 12 replaceable hydrogen atoms with which it could form insoluble salt with metals such as Ca, Fe, Zn, and Mg, thereby reducing their availability in the body (Osagie, 1998). In addition, complex formation of phytic with proteins may inhibit the enzymatic digestion of the protein. (Singh and Krakorian, 1982). Iron and zinc deficiencies occur in populations that subsist on unleavened whole grain bread and rely on it as a primary source of these minerals. Deficiencies have been attributed to the presence of phytates (FAO, 1995). Marfo and Oke (1988) showed that cassava, yam and cocoyam contain 624mg, 637mg and 855mg of phytate per 100g, respectively. Processing methods like cooking has significant effect on the reduction of phytate level in foods. Fermentation reduces the phytate level of foods, sufficiently to nullify its adverse effects (FAO, 1995). The effect of local food processing on phytate levels in cassava, cocoyam, maize, sorghum, rice, cowpea and soybean was observed by Marfo et al. (1990). Seventy two hours of fermentation substantially reduced phytate levels in these food stuffs. Osagie (1998) inferred that the local methods of food processing used in Nigeria
minimise the concerns posed by metal chelation and protein-binding action brought about by the phytate naturally present in food materials of plant origin.

2.4.4 CYANIDE

Cyanogens or cyanogentic glycosides are glycosides whose hydrolyses result in the release of toxic hydrocyanic acid (Okaka et al., 1992). Hydrogen cyanide (HCN) is a constituent of a large number of edible plants. Cyanogens which on hydrolysis in human intestine yields cyanide, are found in such foodstuffs as: lima beans, sweet potatoes, yam, cassava, sugar-cane, peas, cherries, plums, kidney beans (Tyer and Russell, 1989; Okaka et al., 1992). Small amount of foods containing large amounts of glycosides had been associated with chronic neurological effects and anorxia (Walker and Kochar, 1982). In some cases, the result is death (Horning et al., 1983).

The initial symptoms of acute cyanogen poisoning have been described as numbness in fingertips and toes and giddiness or lightheadedness. Small nonfatal doses often produce headache sensations or tightness in both throat and chest, palpitations and general weakness (Tyer and Russell, 1989).

Cyanide is detoxicated, when the enzyme linamarase reacts with linamarin, it is hydrolysed to release toxic hydrocyanic acid which can be readily volatilized by heat or leached by soaking and washing (Okaka et. al., 1992; FAO, 1995). Soaking in water at 30°C. boiling or cooking removes free cyanide but only about
55 percent of the bound cyanide is released after 25 minutes. However, bound cyanide is removed by prolonged soaking (Bourdoux et al., 1983).

Processing like crushing of food before soaking in water could be used to detoxify the cyanogenic glucoside. This is accomplished through the action of the enzyme present in the plant tissue. It breaks down the glucosides to yield free hydrogen cyanide (Walker and Kochhar, 1982).

**2.4.5 PROTEASE**

Protease inhibitors are found in beans, groundnuts and navy beans. All legumes contain trypsin inhibitors in varying degrees, in addition to chymotrypsin inhibitors (Okaka et al., 1992). Inhibition of trypsin and chymotrypsin leads to hypertrophy of pancreas. It is known that trypsin inhibitors inhibit trypsin and chymotrypsin in humans. It reduces protein digestibility, thereby reducing the nutritive value of the seeds (Osho, 1989).

**2.5 PROCESSING TECHNIQUES EMPLOYED TO IMPROVE NUTRITIONAL QUALITY OF PLANT FOODS**

Some of the methods commonly employed for the processing of legumes, cereals and fruits to improve and upgrade their nutritive value include: dehulling, sprouting (germination), soaking and boiling.

**2.5.1 DEHULLING**

Dehulling, which is used in cereal and legume processing involves the removal of the seed hulls (coat). It is an important processing operation in
legumes and cereals because it helps reduce the contents of antinutrients such as tannins which are concentrated in the hulls or testa. Dehulling also helps reduce the fibre and colouring matter in legumes which are concentrated in the hulls. This results in the production of more refined products (Onoja, 1982). Dehulling could be done manually, using hand or mortar and pestle or mechanically. Dehulling reduces cooking time, improves digestibility, texture and appearance of the seed grains (Kurien, 1987; Osho, 1989). However, there may be a considerable nutrient loss during dehulling especially those located in the testa. Some proteins, especially in dry mechanical dehulling are lost (Edijala, 1980). It has been also observed that the quantity of protein loss depends on seed variety (Walker & Kochhar, 1982).

2.5.2 SPROUTING (Germination)

Traditional germinating methods involves the soaking of the seed grains in water for some hours, then keeping them in damp for two or three days and finally drying them. The dried cereal grains are then pounded using a traditional large pestle and mortar (Latham, 1997). Sprouting is a natural, cost effective and simple method of processing food cereals and legumes (Obizoba, 1990). Hormones are produced and enzymes mobilized to convert stored foods such as insoluble CHO and proteins to soluble components. CHO are converted to soluble sugars such as maltose and glucose by various enzymes. Alpha- and beta-
amyloses convert starch into glucose and maltose which are utilized by the germinating seeds (Enwere, 1998).

Germination is known to improve the nutrient content of seeds. Germination of grains provides a convenient method of increasing the energy density and digestibility of foods (Obizoba, 1988; FAO, 1989). Sprouted seeds were reported to show decrease in phytic acid content which consequently resulted in increased availability of minerals (Kings and Burgess, 1993). Sprouting has been demonstrated to be an effective means of reducing antinutritional physiological factors such as polyphenols (tannins) (Hus et al., 1986). A combination of sprouting and cooking resulted in an excellent digestibility coefficient (Ologhobo and Fetuga, 1985). In preparations of some food, germination is combined with fermentation to produce a sour, malted flavour, which is preferred in many communities. The initial enzymatic changes, which precede germination, result in both transfer and increase of the B-complex vitamins and at the same time break down the higher CHO and other storage molecules such as calcium, magnesium and phytate. It is possible to produce a more nutritious flour with a low fibre content, because of these changes (FAO, 1989).

2.5.3 SOAKING

Prior to germination, seeds are first soaked in water to imbibe sufficient water to act as a solvent, reactant and medium for transport of nutrients during the
germination process. Unsoaked seeds cannot be germinated (Enwere, 1998). Soaking reduces the levels of antinutritional factors. Iyer et al. (1980), Noah et al. (1980) and Kossen and Bakowski (1986) reported that soaking improved biological value (BV) of some Egyptian legumes. They attributed it to the leaching of some antinutrients in the soaking water. FAO (1990) reported that soaking of cassava tuber in water improves detoxification as cells are broken by osmosis and fermentation, which facilitates hydrolysis such as soybean in water, aqueous citric acid, or alkali such as sodium bicarbonate helps to leach out colouring matter and substances that impart beany flavour in soymilk and other soy products (STS, 1987). Soaking is a very useful unit operation, if carefully controlled. However, soaking may lead to some loss of essential nutrients as minerals, proteinaceous bodies, pectic substance and other soluble solutes located in the brain of the seed (Enwere, 1998). It can also impose great danger to food quality and to the consumer, especially if the soak water is contaminated by dangerous chemicals and microorganisms (Ngoddy, 1989; Enwere, 1998).

2.5.4 HEAT TREATMENT

Of all the major food processing treatment in current use, heat processing is the most encountered and it has a very important effect on various food components and quality (Enwere, 1998). The application of heat to a food may have beneficial effects by increasing palatability and digestibility. Heat improves
digestibility by destroying trypsin inhibitors and various toxins (Tannenbaum, 1988).

Cooking, boiling, blanching, broiling, simmering, roasting, toasting, baking, frying, warming and steaming, usually done at atmospheric pressure are heat treatment done at about 100°C. Although the frying oil or the baking oven may be at temperature above 100°C until all the moisture (boiling point of 100°C) has been evaporated (Enwere, 1998). The beneficial effect of heat treatment enhances the quality of food while the detrimental effect injures quality. Beneficial effects of heating are varied and numerous. Heating generally inactivates the enzymes responsible for quality deterioration of foods (William et al., 1986).

Colour and flavour are developed in baking, frying, roasting and toasting. Foods such as biscuits, meat extracts and breakfast cereals derive much of their flavour from heat treatment. However, there is some loss of amino acids when these flavours are produced, especially on continued heating. Digestibility of sulphur containing amino acids is improved by conventional heat treatment (Nnam, 1994). Boiling not only improves the sensory properties of legumes but also increases their nutritional qualities (Carpenter, 1981; Walker and Kochhar, 1982). Cooking improved the protein efficiency ratios (PER) as reported by many workers. Moist heat improved the protein quality to a greater extent than did dry
heat (Hemanahini et al., 1980). Most proteins of plant origin are nutritionally improved by heat treatment.

Heating leads to the gelatinization of starch and the denaturation of protein and to other interactions involving other ingredients in food. These changes alter the texture, taste, digestibility, and acceptability of the products. The colour, flavour, and aroma development in cooked, baked, fried, puffed, toasted, and roasted products such as bread, biscuits, cookies, cakes, cereal, fruits, vegetables, and legume products contribute to their overall acceptability (Euwere, 1998).

Trypsin inhibitors, chymotrypsin inhibitors, amylase inhibitors, saponins, toxic acid, goitrins and other nutritional stress factors are either inactivated, destroyed, reduced, or altered by proper heat treatment especially when combined with other processes such as soaking, germination and fermentation (Ogunimein, 1993).
CHAPTER THREE
MATERIALS AND METHODS

Materials

"Acha" - hungry rice (Digitaria exilis); sesame (Sesamum indicum); breadfruit (Artocarpus altilis) were used for the study (Plate 1 F). Sesame and "acha", were purchased from Lafia market, Nasarawa State. Seedless breadfruit was purchased from Egherma and Obakpa markets, in Imo and Enugu States.

3.1 PREPARATION OF MATERIALS (FIGS 1, II AND III - pages 41, 42, 43).

3.1.1 CLEANING

Sesame and "acha" seeds were picked separately to remove foreign materials like sand, stones, sticks, stems and unwanted particles. The wholesome seeds were washed separately.

3.1.2 SESAME (dehulling)

The seeds were divided into two equal parts. One portion was soaked in cold water in a ratio of 1:3 (w/v:liquid) for 8 h. At the end of the soaking period, the seeds were completely drained and partially dried in an air oven at 55°C for 4 h. The dried seeds were dehulled manually and winnowed to remove the hulls. The undehulled and the dehulled seeds were dried separately in an air oven at 55°C for 12 h to 96% dry matter. The dried samples were each milled in a laboratory hammer mill (20 mm mesh screen) to a fine flour.
3.1.3 "Acha" (sprouting)

The grains were divided into two parts. One portion was not sprouted. The other portion was soaked in water for 4 h at the ratio of 1:3 w/v. At the end of the soaking period, the water was completely drained. The sample was put in black polythene bag, knotted loosely and left to sprout for two days (48 h). The sprouting sample was washed twice daily to avoid growth of mould. The sprouted sample was dried in an air oven at 55°C to 96% dry matter. The grains were dehulled and winnowed to remove the hulls. The unsprouted grains were also dried in an air oven at 55°C to 96% dry matter. Both the unsprouted and the sprouted grains were milled separately to a fine flour using laboratory hammer-mill (70 mm-mesh screen).

3.1.4 BREADFRUIT (boiling)

The fruits were washed, peeled and cut into pieces each. They were then divided into two equal parts. One portion was boiled for 10 minutes and flaked. The unboiled portion was also flaked. Both the boiled and unboiled samples were dried separately in an air oven at 55°C to 96% dry matter. The dried samples were each milled in a laboratory hammer-mill (70 mm-mesh screen) to a fine flour.
Plate 1: Seeds and fruit used for the study: A - Sesame, B - "Acha", C - Seedless breadfruit.

The flour from each of the samples was packed separately in polythene bags and stored at 15°C for use in the study.
3.1.5 FORMULATION OF COMPOSITE FLOURS (Plate 2 - page 40)

The processed flours (sesame “acha” and breadfruit) were used to formulate the composite in the following ratio:

<table>
<thead>
<tr>
<th>Sesame</th>
<th>&quot;Acha&quot;</th>
<th>Breadfruit</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>15</td>
<td>15</td>
<td>70:15:15</td>
</tr>
<tr>
<td>60</td>
<td>25</td>
<td>15</td>
<td>60:25:15</td>
</tr>
<tr>
<td>60</td>
<td>15</td>
<td>25</td>
<td>60:15:25</td>
</tr>
<tr>
<td>15</td>
<td>60</td>
<td>25</td>
<td>15:60:25</td>
</tr>
</tbody>
</table>
Plate 2: Composite flour used for the product development

A - Processed sesame, “acha” and seedless breadfruit (70:15:15)
B - Processed sesame, “acha” and seedless breadfruit (60:25:15)
C - Processed sesame, “acha” and seedless breadfruit (60:15:25)
D - Unprocessed sesame, “acha” and seedless breadfruit (70:15:15)
E - Unprocessed sesame, “acha” and seedless breadfruit (60:25:15)
F - Unprocessed sesame, “acha” and seedless breadfruit (60:15:25)
G - Unprocessed sesame, “acha” and seedless breadfruit (15:60:25)
H - Unprocessed sesame, “acha” and seedless breadfruit (15:60:25)
Fig 1: Flow diagram for processing of undehulled and dehulled sesame floors.
Fig 2: Flow diagram for processing of unsprouted and sprouted acha seeds into flours.
Fig 3: Flow diagram for processing of unboiled and boiled breadfruit flours.
3.2 CHEMICAL ANALYSIS

3.2.1 PROXIMATE

The proximate analysis of the individual flours were done in triplicate.

Crude Protein

Total nitrogen (N) was determined by the official micro-Kjeldahl method of AOAC (1995). Crude protein was estimated by multiplying nitrogen value with conversion factor 6.25 (N x 6.25) (details in Appendix A).

Total Lipids

This was estimated using the Pearson modified method (1976), with the Tecator Soxtec apparatus (Appendix B).

Total Ash

It was estimated by incineration of known weights of sample in a muffle furnace at 550-600°C using the AOAC (1990) procedure (appendix C).

Residual Moisture

Two grammes of each sample were weighed into a tared aluminum dish and placed in an oven overnight at 105°C to a constant weight. A factor (F) was calculated which enabled all calculations to be done on dry matter basis.

\[ F = \frac{100}{100 - \text{moisture value}} \]

(Polaecchi, 1985) (Appendix D).

Carbohydrate

This was calculated by the difference method (Appendix E).
Crude Fibre

The crude fibre content of the samples was determined by the official method of AOAC (1990) (Appendix F).

3.2.2 VITAMIN

Ascorbic acid was determined by the 2, 6-dichloroindophenol method. Five grammes of each sample were macerated with 5% metaphosphoric acid; acetone was added and sample titrated until a faint pink colour was obtained (see Appendix G).

3.2.3 MINERALS: CALCIUM (Ca), IRON (Fe), IODINE (I), ZINC (Zn) AND PHOSPHORUS (P)

Minerals were determined using a Perkin Elmer Model 303 Atomic absorption spectrophotometer after ashing of samples and extracting with 0.2M HCl solution (Appendix H).

3.2.4 TANNINS

This was determined by the modified Vanillin-HCl method as described by Price and Butler (1977) (Appendix I).

3.2.5 PHYTATE

Determination of phytate was carried out using the modified procedure adapted from Holand and Oberless (1977) (Appendix J).

3.2.6 CYANIDE

This was determined using an Orion Model EATM 920 research expandable ion analyzer; equipped with the cyanide ion selective electrode, according to the manufacturer's manual. Before the assay, the samples were hydrolyzed according to
3.3 ORGANOLEPTIC STUDY

Development of products

Biscuits and gruels were produced from the composite flours for sensory evaluation. A standard recipe was developed for the preparation of each product. Pilot testing sessions were organised for each product to standardise the recipe (see Appendix L for the recipe).

Development of instruments

A nine point hedonic scale was adopted for the sensory evaluation (Amerine et al; 1965; Pigot, 1984). The attributes used in describing flavour, texture and colour of each product were included in the instrument. Food Attitude and Rating Forms (FARF) were used for assessing general acceptability of the products.

Panel selection

Thirty panelists were selected for the sensory evaluation. They were made up of lecturers, instructors and students in the Departments of Food Science and Technology and Home Science and Nutrition. They were familiar with the qualities of the products and had participated in numerous testing sessions.

Evaluation session

The evaluation was done in a day. Twenty judges turned up in the morning session while ten judges turned up in the evening of the same day. On arrival, the judges were reminded of the purpose of the study. They were instructed on the use of the scoring sheet and the importance of their independence in judging the products. The judges were served with a small plate to place the products (samples) while
evaluating. A glass of water was given to rinse the mouth after each testing. This was to avoid a carry over effect from the preceding sample. The work units served as tables. Each product with its evaluation form was kept on a separate work unit. The judges evaluated each product using the appropriate instrument. The evaluation forms for each product were collected separately at the end of each testing session.

3.3.1 CHEMICAL EVALUATION OF THE PRODUCTS

The proximate, mineral and vitamin (ascorbic acid) composition of the products were done in triplicate, using the same methods applied on the individual flows.

3.4 STORAGE STUDIES

The samples (biscuits) tested organoleptically were stored at both ambient (38°C) and refrigerator (6°C) temperature and monitored to determine the keeping qualities according to Harrigan and McCance (1970) method.

3.5 STATISTICAL ANALYSIS

Data collected were subjected to one way analysis of variance (ANOVA). Duncan’s New Multiple Range Test (DNMR) and Least Significance Difference (LSD) Test (Steel and Torrie, 1960; Obi, 1986) were used to separate means. Also, a two-tail group t-test was used to determine differences between treatment (variable) means using statistical package for social sciences (SPSS) for MS Windows. Release 6.0 in which equality of variance, was estimated according to Levene’s Test.